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TECHNICAL MEMORANDUM
WASTE CONDITIONING STUDY
FOR PIT B WASTE

BAILEY SUPERFUND SITE
ORANGE COUNTY, TEXAS

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1. TERMS OF REFERENCE

This document has been prepared by GeoSyntec Consultants, Atlanta, Georgia (GeoSyntec) on behalf of the Bailey Site Settlors Committee (BSSC) to present the results of the bench-scale waste conditioning study conducted on waste present in Pit B at the Bailey Superfund Site, located in Orange County, Texas. The purpose of the waste conditioning study was to evaluate the technical feasibility and effectiveness of different waste conditioning techniques at reducing reactive sulfide levels that were reported in the Pit B waste.

2. STUDY OBJECTIVE

The background of and reasons for conducting the Pit B Pre-design Study (PDS) are presented in the main body of the Pit B PDS Report. The objective of the waste conditioning study is to evaluate (i) the likely source of reactive sulfides that were found in the collected samples of Pit B waste; and (ii) the types of waste conditioning required to reduce the levels of reactive sulfide present (if any) in the Pit B waste stream to less than the EPA Interim Guidance level of 500 mg/kg. The reagents tested were lime, ferric chloride ($FeCl_3$) plus lime, and hydrogen peroxide (H_2O_2) plus lime. The rationale for the selection of these specific reagents is summarized in Section 3.1. Bulk samples of waste were collected from Pit B in the areas thought to contain the highest concentrations reactive sulfide (i.e., up to 1,600 mg/kg reactive H_2S based on results of the PDS sampling events) were collected for evaluation during the waste conditioning study. Varying dosage rates of the reagents considered for the waste conditioning study were evaluated in order to evaluate the lowest dosage possible to reduce the concentration of reactive sulfide. The contributions of all deactivation mechanisms, including dilution, oxidation, precipitation, and pH adjustment/solidification to the disappearance of reactive sulfide were evaluated during the course of this study.

3. EXPERIMENTAL PROTOCOL/RATIONALE

3.1 Deactivation Mechanisms

Sulfide is a regulated constituent under the Resource Conservation and Recovery Act (RCRA) because of its toxicity. Wastes containing sulfide are regulated under RCRA as reactive (D003 waste code) wastes if, at pH values between 2 and 12, the waste will release toxic amounts of sulfide as H_2S gas. The generation of H_2S can be precluded by alkaline pH adjustment or by removing the total reactive sulfide from the waste stream. The latter procedure can be achieved by oxidizing the sulfide present in the waste to sulfate, a relatively non-toxic form of sulfur, in the presence of an oxidizing agent or by precipitation of sulfide as an insoluble compound. The following sections describe the chemical processes evaluated during the waste conditioning study.

3.1.1 pH Adjustment

In aqueous solutions, such as those present in the Pit B waste, soluble sulfide anions exist in pH-dependent forms, as demonstrated by the chemical equilibria presented below:

$$S^{2-} \xleftrightarrow{H^+} HS^- \xleftrightarrow{H^+} H_2S \uparrow$$

High pH   *Low pH*
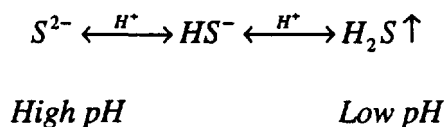
In acidic conditions, in the absence of chelating (binding) agents, sulfide will exist as hydrogen sulfide gas (H_2S). Similarly, in alkaline, non-chlelating conditions, sulfide will exist as the soluble sulfide anion (S^{2-}). Since reactive sulfide is defined as that sulfide which will be released to the atmosphere as hydrogen sulfide gas (H_2S) between pH 2 and 12, any agent which increases the alkalinity of the material (by increasing its pH), could mitigate the emission of H_2S.

A common industrial reagent used for this purpose is lime (calcium oxide, CaO). Lime increases the pH of an aqueous solution by the following chemical reaction.

$$CaO + H_2O \longleftrightarrow Ca^{2+} + 2OH^-$$
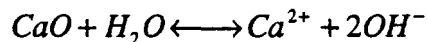
Thus, when lime is added to the waste, the pH is raised, the sulfide anion (S^{2-}) is predominantly formed, and the generation of H_2S is precluded.

3.1.2 Oxidation

A common industrial chemical that has been employed as an oxidizing agent is hydrogen peroxide, H_2O_2. Hydrogen peroxide oxidizes soluble sulfide to sulfate primarily by the following reaction.

$$8H_2O_2 + S^{2-} \xrightarrow{\quad\quad} SO_4^{2-} + 8H_2O + 2O_2$$
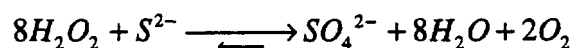
Stoichiometrically, an 8:1 H_2O_2:S^{2-} ratio is required to completely oxidize sulfide to sulfate. This is a relationship postulated based on the absence of any other reactive species which may also consume the H_2O_2 added. As this is obviously not the case in the Pit B waste material (i.e., there are other compounds, principally organics which will be oxidized by H_2O_2 addition) in the waste conditioning study, a stoichiometric relationship of greater than 8:1 H_2O_2:S^{2-} will be added as an upper limit for H_2O_2 addition. Once formed, sulfate will not generate H_2S unless exposed to a reducing agent. Thus, the waste has been deactivated with regard to sulfide reactivity.

Because the only form of peroxide readily available for the waste conditioning study was 3% H_2O_2, a substantial increase in the moisture content of the waste was caused by the addition of a sufficient quantity of the H_2O_2 solution to oxidize the known quantities of sulfide present (detected at concentrations up to 1,600 mg/kg). While the concentration of the H_2O_2 that would be used in the full-scale application of this technique will be much higher (approximately 30%) than that observed in the waste conditioning study, a similar increase in moisture content can be expected. In anticipation of this problem, the treated material will be stabilized with lime, for the dual purpose of waste solidification and also to raise the pH of the treated material, thus

altering the state of any unreacted sulfide to the sulfide anion (S^{2-}), precluding the formation of H_2S.
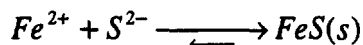
3.1.3 Precipitation

The most effective agents for sulfide precipitation are generally metallic cations. A relatively non-toxic metallic cation that has been widely used for this purpose is ferric iron (iron in the +3 valence state). Ferric iron (Fe^{3+}) is commercially available as ferric chloride ($FeCl_3$) and reacts with soluble sulfide by the following reaction.

$$2FeCl_3 + 3S^{2-} \xrightleftharpoons{} Fe_2S_3(s) + 6Cl^-$$

The ferric sulfide (Fe_2S_3) precipitated is very insoluble ($K_{sp}=1.4 \times 10^{-88}$), even in the presence of acid. Thus, in a complete reaction, soluble sulfide is removed from solution and will not convert to gaseous H_2S. By the stoichiometry above, $FeCl_3$ reacts with soluble sulfide in a 2:3 ratio. It should also be noted that $FeCl_3$ can also be reduced to ferrous sulfide in the presence of a mild reducing agent, likely to be found in the Pit B waste. That reduction occurs by the reactions given below:

$$Fe^{3+} \xleftarrow{e^-} Fe^{2+}$$
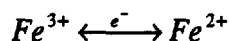
The reducing agent in question could be the sulfide itself, being converted to sulfate or another oxidized form of sulfur (e.g., sulfur, sulfite, thiosulfate, etc.). The primary oxidation reaction for sulfide has been discussed previously. If, however, there is sulfide remaining in the presence of ferrous (Fe^{2+}) iron, ferrous sulfide (FeS) can be precipitated by the following reaction.

$$Fe^{2+} + S^{2-} \xrightleftharpoons{} FeS(s)$$

Ferrous sulfide is also insoluble in water ($K_{sp}=4.9 \times 10^{-18}$), even in the presence of acid. The degree, if any, to which the oxidation of Fe^{3+} to Fe^{2+} will occur is not known. However, if it does occur, sulfide should be precipitated by a similar mechanism.

Due to the solubility limits of $FeCl_3$ in water, relatively dilute concentrations were used in the waste conditioning study, thus resulting in a substantial increase in the moisture content of the treated waste. Therefore, the iron conditioned material was stabilized with lime for the same reasons as was the H_2O_2 conditioned material.

3.1.4 Dilution

Because external agents were added to the waste for the purposes of treatment, some degree of mass dilution will occur, independent of chemical reactions under consideration. The degree to which reactive sulfide disappearance will occur due to dilution was evaluated during the waste conditioning study by mathematically adjusting the post-conditioning concentrations prior to rendering any conclusions as to waste conditioning effectiveness.

3.2 Experimental Protocol

The procedures implemented for this study are summarized below by conditioning level under consideration. Table 1 provides a listing of all samples collected for the waste conditioning study, their corresponding conditioning level, and the chemical analyses performed on each.

Pretesting

1. Three bulk samples (approximately 40 pounds each) were collected in a five gallon bucket from sampling locations A3, D2, and B3, the most heavily contaminated areas of Pit B with regard to reactive sulfide. These samples were shipped to the GeoSyntec Atlanta Laboratory.
2. Upon arrival, sample D2 was homogenized, subsampled in triplicate, and analyzed for reactive sulfide by SW-846 Chapter 7 Method, and total sulfide by SW Method 9030A. Bulk samples A3 and B3 were sampled (three samples from bulk sample A3; one sample from bulk sample B3) for screening purposes and analyzed for reactive and total sulfide. These bulk samples were held in reserve to evaluate the remainder of the Pit B waste in the event that analysis of the sample from location D2 proved unenlightening.

Experimental Procedures:

Stabilization

1. An aliquot of the original sample (approximately 3000 g in weight) was collected.
2. This aliquot was split into thirds (approximately 1000 g each wet weight).
3. A known amount of lime was added to each aliquot. The amounts of lime added were 15, 25 and 40% reagent:waste final ratios.
4. The solution/waste material was mixed thoroughly and allowed to stand for five minutes.
5. Duplicate subsamples were collected from each concentration of lime added and analyzed for reactive sulfide by SW-846 Chapter 7 Method, total sulfide by SW Method 9030A, pH by SW Method 9045C, paint filter by SW Method 9095, and for moisture content by ASTM Method D 2216.
6. Waste handling and mixing operations were performed under controlled conditions (i.e., in a fume hood). The headspace of the mixing container was monitored with Draeger tubes to detect the generation of H_2S gas.

Iron Precipitation

1. An aliquot of the original sample (approximately 3000 g in weight) was collected.
2. This aliquot was split into thirds (approximately 1000 g each wet weight).
3. Ferric chloride was added to each waste aliquot. The concentrations of $FeCl_3$ added were 6, 15, and 30 g $FeCl_3$ per kg waste; each amount of $FeCl_3$ added was dissolved in 100 ml water. Following $FeCl_3$ addition, the waste was mixed thoroughly and subsequently subsampled in duplicate and analyzed for reactive sulfide by SW-846 Chapter 7 Method, total sulfide by SW Method 9030A, pH by SW Method 9045C, paint filter by SW Method 9095, and for moisture content by ASTM Method D 2216.
4. The remaining conditioned material (after subsample collection) was stabilized with 25% (adjusted weight) lime.
5. The waste material was mixed thoroughly and allowed to stand for five minutes.
6. Duplicate subsamples were collected for each concentration of $FeCl_3$ added and analyzed for reactive sulfide by SW-846 Chapter 7 Method, total sulfide by SW

Method 9030A, pH by SW Method 9045C, paint filter by SW Method 9095, and for moisture content by ASTM Method D 2216.

7. Waste handling and mixing operations were performed under controlled conditions (i.e., in a fume hood). The headspace of the mixing container was monitored with Draeger tubes to detect the generation of H_2S gas.

Peroxide Oxidation

1. An aliquot of the original sample (approximately 1000 g in weight) was collected.
2. A total of 9 g of H_2O_2 (300 ml 3% solution) was added to this material. Following H_2O_2 addition, the waste was allowed to stand for five minutes and then it was subsampled in duplicate and analyzed for reactive sulfide by SW-846 Chapter 7 Method, total sulfide by SW Method 9030A, pH by SW Method 9045C, paint filter by SW Method 9095, and for moisture content by ASTM Method D 2216.
3. The H_2O_2 conditioned waste was stabilized with 25% lime (adjusted weight).
4. The solution/waste material was mixed thoroughly and allowed to stand for five minutes.
5. Duplicate subsamples were collected from the H_2O_2 conditioned/lime stabilized material and analyzed for reactive sulfide by SW-846 Chapter 7 Method, total sulfide by SW Method 9030A, pH by SW Method 9045C, paint filter by SW Method 9095, and for moisture content by ASTM Method D 2216.
6. Waste handling and mixing operations were performed under controlled conditions (i.e., in a fume hood). The headspace of the mixing container was monitored with Draeger tubes to detect the generation of H_2S gas.

4. RESULTS

4.1 Visual Results Summary

Generally, the reagents applied mixed fairly well with the waste. Hydrogen sulfide was not emitted from any of the waste samples tested at levels detectable with Draeger tubes. For the replicate waste sample conditioned with H_2O_2, it did not appear as though oxygen was emitted from the material (as O_2 bubbles); a noticeable increase in heat was observed from this replicate when lime was added to it, however.

4.2 Pre-Conditioning Results Summary

All three bulk samples analyzed (A3, B3, and D2) contained reactive sulfide concentrations less than 500 mg/kg prior to initiating the waste conditioning study (Table 2), although bulk sample D2 appeared to contain the highest concentration of reactive sulfide (up to 260 mg/kg; Table 2). Since these results were not consistent with those obtained from previous samples of waste collected from Pit B, samples of the water and sediment overlying the waste at location D3 in Pit B were collected and analyzed for total and reactive sulfides in an attempt to identify the potential source of the reactive sulfides. These data are summarized in Table 2.

4.3 Analytical Results Summary

Table 3 presents the results of chemical analyses performed during the waste conditioning study. Table 4 presents the results of these analyses after adjustment for dilution.

For bulk sample D2, the pre-conditioning sampling concentrations of reactive sulfide ranged from 200 to 260 mg/kg (Table 3). Most of the reactive sulfide data were extremely variable in the conditioned waste samples, exhibiting sampling error rates, when computable, of 84% to 125% (Table 3). The end result of the variability in the data is that any data trends are suspect.

Total sulfide was analyzed to provide an additional level of control on the results obtained from the waste conditioning agents applied. However, since the total sulfide

levels in the waste material prior to conditioning were less than post-conditioning total sulfide values (Table 2), and because these values were also less than the reactive sulfide values in the same set of samples (Table 3), conclusions based on the total sulfide data cannot be made. The heterogeneous nature of the waste, as evidenced by the high sampling error rates observed for both total and reactive sulfide measured for both the pre- and post-conditioning waste samples, is the likely reason for this apparent disparity.

Lime conditioning may have reduced the reactive sulfide levels in the Pit B waste samples, although variability in the experimental data precludes a positive determination in this regard. For the 15% addition of lime, the reactive sulfide levels may have been reduced up to 26% (Table 4); for the 25% lime addition, reactive sulfide levels may have been reduced up to 43% (Table 4). However, the enormous variation (113-120%) in the analytical data set (Table 4) suggests that this reduction is not significant. The 40% addition of lime apparently reduced the reactive sulfide levels to non-detect (<50 mg/kg; Table 4). In each case, the conditioned material passed the paint filter test, whereas the pre-conditioned material did not, and the pH of the material was dramatically increased, from a pre-conditioned mean of 6.1 to a post-conditioned mean of 12.4 (all lime application rates; Table 4).

Ferric chloride conditioning mediated a reduction in reactive sulfide levels. The 6 g $FeCl_3$/kg application rate did not cause a significant reduction in reactive sulfide levels (Table 4). A significant reduction (to less than the 50 mg/kg detection limit) was noted for the 15 and 30 g $FeCl_3$/kg application rates, however (Table 4). The pH of the material was reduced (made acidic) by the addition of $FeCl_3$ (reduced to approximately pH 2.5 at a dosage rate of 30 g $FeCl_3$/kg; Table 4), which is not surprising since ferric chloride can act as a Lewis acid. When lime was to the ferric chloride conditioned samples, increases in pH were noted (up to pH 12.5; Table 4). The addition of lime significantly reduced the reactive sulfide levels for the 6 g $FeCl_3$/kg application rate (Table 4); no significant change in reactive sulfide levels in the 15 and 30 g $FeCl_3$/kg application rates due to the subsequent addition of lime was noted, however (Table 4).

Hydrogen peroxide, applied at a rate of 9 g H_2O_2/kg waste, reduced the reactive sulfide levels to less than the detection limit of 50 mg/kg and lowered the pH of the material to 4.9 (Table 4). The addition of lime increased the pH of the hydrogen peroxide treated material to 12.45 without a significant change in reactive sulfide levels (Table 4).

5.   DISCUSSION

The levels of reactive sulfide in bulk samples A3 and B3 were less than the interim guidance threshold of 500 mg/kg for both samples analyzed (Table 2).   This data coupled with the observed concentrations of reactive sulfide in the D2 sample prior to conditioning suggests both that the tarry waste in Pit B, when excavated using a backhoe or other heavy equipment, does not contain reactive sulfide in a concentration greater than 500 mg/kg and that the reactive sulfide levels obtained in earlier Pit B investigations may have come from sampling artifact or another source.   A possible source of reactive sulfide in a marsh environment is the sediment; this possibility was investigated as follows.

While at the Bailey site during the execution of the Sitewide Pre-design Study, GeoSyntec personnel collected samples of the sediment and water in Pit B from location D2.   The water sample contained 1.1 mg/L reactive sulfide; the sediment sample contained 800 mg/kg reactive sulfide wet weight; 5700 mg/kg reactive sulfide dry weight (Table 2).   It is GeoSyntec's opinion that the marsh sediment on top of Pit B is the source of the reactive sulfide detected in the Pit B samples.

With regard to the waste conditioning study, it can generally be concluded that the addition of lime caused a reduction in the levels of reactive sulfide in the Pit B wastes, although the mechanism by which this reduction occurred (dilution or pH adjustment) as well as the minimum lime dosage rate required are uncertain, due to the heterogeneity of waste material, manifested by huge error rates in the samples collected from it (pre- and post-conditioning). A similar statement can be made for ferric chloride addition.   Hydrogen peroxide conditioning appeared to reduce the levels of reactive sulfide, but the mechanism by which this was accomplished (i.e., dilution or sulfide oxidation) is unknown.

6. RECOMMENDATION

Because of the relatively inconclusive nature of the waste conditioning study results, and because of the identification of the marsh sediments as the probable source of the reactive sulfide, GeoSyntec recommends an on-site demonstration of the effectiveness of lime conditioning with a larger sample size to confirm that lime conditioning can be used to reduce the concentration of reactive sulfide to less than 500 mg/kg. The waste conditioning process will also serve to improve the handleability of the waste material. The protocol for this demonstration will be developed and addressed under separate cover.

TABLES

Table 1. Sample Identification and Analyses Performed
Pit B Waste Conditioning Study
Bailey Superfund Site, Orange, Texas

Level	Sample Name	Analyses Performed				
		Total Sulfide (SW 9030A)	Reactive Sulfide (SW-846, Chapter 7)	pH (SW 9045C)	Moisture (ASTM D2216)	Paint Filter (SW 9095)
Pre-Conditioning	D2	X	X			
	D2	X	X			
	D2	X	X			
15% Lime'	D2-S1-1	X	X	X	X	X
	D2-S1-2	X	X	X	X	X
25% Lime	D2-S2-1	X	X	X	X	X
	D2-S2-2	X	X	X	X	X
40% Lime	D2-S3-1	X	X	X	X	X
	D2-S3-2	X	X	X	X	X
Iron (6)	D2-FE1-1	X	X	X	X	X
	D2-FE1-2	X	X	X	X	X
Iron (6) + lime	D2-FE1-S-1	X	X	X	X	X
	D2-FE1-S-2	X	X	X	X	X
Iron (15)	D2-FE2-1	X	X	X	X	X
	D2-FE2-2	X	X	X	X	X
Iron (15) + lime	D2-FE2-S-1	X	X	X	X	X
	D2-FE2-S-2	X	X	X	X	X
Iron (30)	D2-FE3-1	X	X	X	X	X
	D2-FE3-2	X	X	X	X	X
Iron (30) + lime	D2-FE3-S-1	X	X	X	X	X
	D2-FE3-S-2	X	X	X	X	X
H_2O_2 (300)	D2-OX1-1	X	X	X	X	X
	D2-OX1-2	X	X	X	X	X
H_2O_2 (300) + lime	D2-OX1-S-1	X	X	X	X	X
	D2-OX1-S-2	X	X	X	X	X

Table 2. Bulk Sample Pre-Conditioning and Marsh Sediment Data
Pit B Waste Conditioning Study
Bailey Superfund Site, Orange, Texas

Level	Identification	Sample Name	Analyses and Results Performed				
			Total Sulfide (mg/kg)[a]	Reactive Sulfide (mg/kg)[a]	pH	Moisture (%)	Paint Filter
Pre-Conditioning Pit B Waste	Bulk Sample D2	D2	12	260	6.1	68	Fail[b]
	Bulk Sample D2	D2	11	200	6.1	63	Fail
	Bulk Sample D2	D2	10	200	6.1	68	Fail
	Bulk Sample A3	PRE-1	26	240	5.7	46	Fail
	Bulk Sample A3	PRE-2	38	<50	5.3	41	Fail
	Bulk Sample A3	PRE-3	16	110	5.7	40	Fail
	Bulk Sample B3	B3	33	91	NA	58	NA
D2 Sediment	Sediment from D2	D2-S	9.1	800	7.8	86	NA
D2 Water	Water from D2	D2-W	1.1	<50	7.8	NA	NA

[a] *Units are mg/L for water samples*

[b] *NA, Not Analyzed*

Table 3. Analytical Data Summary
Pit B Waste Conditioning Study
Bailey Superfund Site, Orange, Texas

Level	Parameter	Replicate 1	2	3	Mean[a]	S.E.[a,b]	% Error
Pretreatment	Moisture	68	68	63	66.33	2.04	3%
	pH	6.1	6.1	6.1	6.10	0.00	0%
	Total Sulfide	10	12	11	11.00	0.71	6%
	Reactive Sulfide	200	260	200	220.00	24.49	11%
15% Lime	Moisture	58	58		58.00	0.00	0%
	pH	12.4	12.4		12.40	0.00	0%
	Total Sulfide	250	300		275.00	35.36	13%
	Reactive Sulfide	260	<50		142.50	166.17	117%
25% Lime	Moisture	53	55		54.00	1.41	3%
	pH	12.4	12.4		12.40	0.00	0%
	Total Sulfide	240	85		162.50	109.60	67%
	Reactive Sulfide	180	<50		102.50	109.60	107%
40% Lime	Moisture	46	46		46.00	0.00	0%
	pH	12.4	12.4		12.40	0.00	0%
	Total Sulfide	11	3600		1805.50	2537.81	141%
	Reactive Sulfide	<50	<50		NA[c]	NA	NA
Iron (6)	Moisture	66	64		65.00	1.41	2%
	pH	5.3	5.4		5.35	0.07	1%
	Total Sulfide	34	180		107.00	103.24	96%
	Reactive Sulfide	410	<50		217.50	272.24	125%
Iron (6) + lime	Moisture	55	53		54.00	1.41	3%
	pH	12.4	12.3		12.35	0.07	1%
	Total Sulfide	79	170		124.50	64.35	52%
	Reactive Sulfide	98	<50		61.50	51.62	84%
Iron (15)	Moisture	72	60		66.00	8.49	13%
	pH	4.1	4		4.05	0.07	2%
	Total Sulfide	44	97		70.50	37.48	53%
	Reactive Sulfide	<50	<50		NA	NA	NA
Iron (15) + lime	Moisture	54	56		55.00	1.41	3%
	pH	12.3	12.3		12.30	0.00	0%
	Total Sulfide	120	11		65.50	77.07	118%
	Reactive Sulfide	150	<50		87.50	88.39	101%
Iron (30)	Moisture	61	65		63.00	2.83	4%
	pH	2.6	2.5		2.55	0.07	3%
	Total Sulfide	73	64		68.50	6.36	9%
	Reactive Sulfide	<50	<50		NA	NA	NA
Iron (30) + lime	Moisture	55	56		55.50	0.71	1%
	pH	12.2	12.2		12.20	0.00	0%
	Total Sulfide	180	110		145.00	49.50	34%
	Reactive Sulfide	170	58		114.00	79.20	69%
H_2O_2 (300)	Moisture	59	69		64.00	7.07	11%
	pH	5	4.9		4.95	0.07	1%
	Total Sulfide	170	70		120.00	70.71	59%
	Reactive Sulfide	<50	<50		NA	NA	NA
H_2O_2 (300) + lime	Moisture	64	63		63.50	0.71	1%
	pH	12.4	12.5		12.45	0.07	1%
	Total Sulfide	15	10		12.50	3.54	28%
	Reactive Sulfide	<50	<50		NA	NA	NA

[a] Mean and standard error calculated using 1/2 the detection limit, when at least one, but not all values were non-detect.
[b] S.E., Standard error
[c] NA, Not applicable, all values are non-detect.

Table 4. Analytical Data Summary
Pit B Waste Conditioning Study
(Adjusted for Dilution)
Bailey Superfund Site, Orange, Texas

Level	Parameter	Replicate 1	2	3	Mean[a]	S.E.[a,b]	% Error
Pretreatment	Moisture	68	68	63	66.33	2.04	3%
	pH	6.1	6.1	6.1	6.10	0.00	0%
	Total Sulfide	10	12	11	11.00	0.71	6%
	Reactive Sulfide	200	260	200	220.00	24.49	11%
15% Lime	Moisture	58	58		58.00	0.00	0%
	pH	12.4	12.4		12.40	0.00	0%
	Total Sulfide	288	345		316.25	40.66	13%
	Reactive Sulfide	299	<50		162.00	193.75	120%
25% Lime	Moisture	53	55		54.00	1.41	3%
	pH	12.4	12.4		12.40	0.00	0%
	Total Sulfide	300	106		203.13	137.00	67%
	Reactive Sulfide	225	<50		125.00	141.42	113%
40% Lime	Moisture	46	46		46.00	0.00	0%
	pH	12.4	12.4		12.40	0.00	0%
	Total Sulfide	15	5040		2527.70	3552.93	141%
	Reactive Sulfide	<50	<50		NA[c]	NA	NA
Iron (6)	Moisture	66	64		65.00	1.41	2%
	pH	5.3	5.4		5.35	0.07	1%
	Total Sulfide	38	199		118.34	114.18	96%
	Reactive Sulfide	453	<50		239.23	302.97	127%
Iron (6) + lime	Moisture	55	53		54.00	1.41	3%
	pH	12.4	12.3		12.35	0.07	1%
	Total Sulfide	109	235		172.12	88.96	52%
	Reactive Sulfide	135	<50		80.24	78.12	97%
Iron (15)	Moisture	72	60		66.00	8.49	13%
	pH	4.1	4		4.05	0.07	2%
	Total Sulfide	49	108		78.61	41.79	53%
	Reactive Sulfide	<50	<50		NA	NA	NA
Iron (15) + lime	Moisture	54	56		55.00	1.41	3%
	pH	12.3	12.3		12.30	0.00	0%
	Total Sulfide	167	15		91.29	107.42	118%
	Reactive Sulfide	209	<50		117.03	130.15	111%
Iron (30)	Moisture	61	65		63.00	2.83	4%
	pH	2.6	2.5		2.55	0.07	3%
	Total Sulfide	82	72		77.41	7.19	9%
	Reactive Sulfide	<50	<50		NA	NA	NA
Iron (30) + lime	Moisture	55	56		55.50	0.71	1%
	pH	12.2	12.2		12.20	0.00	0%
	Total Sulfide	254	155		204.81	69.92	34%
	Reactive Sulfide	240	82		161.03	111.86	69%
H_2O_2 (300)	Moisture	59	69	63	64.00	7.07	11%
	pH	5	4.9		4.95	0.07	1%
	Total Sulfide	221	91		156.00	91.92	59%
	Reactive Sulfide	<50	<50		NA	NA	NA
H_2O_2 (300) + lime	Moisture	64	63		63.50	0.71	1%
	pH	12.4	12.5		12.45	0.07	1%
	Total Sulfide	24	16		20.31	5.75	28%
	Reactive Sulfide	<50	<50		NA	NA	NA

[a] Mean and standard error calculated using 1/2 the detection limit, when at least one, but not all values were non-detect.
[b] S.E., Standard error
[c] NA, Not applicable, all values are non-detect.